Earth Science Enterprise Technology Planning Workshop

Innovative Technology

Lou Schuster (Co-Chair) - NASA-HQ
Barbara Wilson (Co-Chair) - JPL
Martin Buehler (Facilitator) - JPL

January 23-24, 2001

Innovative Technologies

- **Focus:**
  - **A forum to discuss candidate technologies not included in other breakout sessions in this workshop.**

- **Candidate Technologies:**
  - **Discuss *science capability needs*.**
  - **Provide current and future *TRLs* (Technology Readiness Levels).**
  - **Discuss the *flight validation rationale*.**
  - **Discuss possible *flight validation scenarios* for component, sub-system or system-level validation.**

Earth Science Enterprise Technology Planning Workshop
Innovative Technologies

Agenda:

Tuesday, Jan 23, 2001

TOPIC	PRESENTER	INSITIUTION
Advanced Two-Phase Thermal Control	Ted Swanson	GSFC
Miniature-Loop Heat Pipes	Dan Butler	GSFC
ElectroHydroDynamic (EHD) Pumped Thermal Control Systems	Jeffrey Didion	GSFC
Deployable Concentrating Solar Cell Array	Michael Brown	NRL
Space Environmental Effects	Richard Worsfold	CRESTech
Flight Qualification Techniques	W. "JR" Dreier, Jr.	Center for Naval Analysis
Sensor Craft	Barry Meredith	LaRC
Terrestrial Fluorescence	Theisen	Stennis
Quantum Technology	Klipstein	JPL
MEMS/Nano scale	Garrison Darrin	JHU/APL
Active Carbon/Carbon Structural Radiator	Liz Shinn	AFRL

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Agenda:

Wednesday, Jan 24, 2001

Identify Science needs and candidate Technology approaches

- new capabilities enabled
- reductions in implementation and life-cycle costs

Define specific capability/technology needs for each measurement class
Describe and illustrate the current state of the art for the technology

Itemize the major technology components and current TRLs.

Identify ongoing investments

Identify technology development gaps

Formulate draft technology development roadmaps

- Show key development and flight validation objectives and milestones
  - Ground development and validation needed
  - include technology flight validation where necessary

Summary Plenary Session

- 10-minute presentations by Chairs of each Breakout Session

Adjourn

Innovative Technologies: Participants

NAME	INSTITUTION
Ted Swanson	GSFC
Dan Butler	GSFC
Jeffrey Didion	GSFC
Mike Brown	NRL
Richard Worsfold	CRESTech Toronto, Can
W. "JR" Dreier, Jr.	Center for Naval Analysis
Barry Meredith	LaRC
Clayton Turner	LaRC
Arnold Theisen	NASA/SSC/ GADD (NRC)

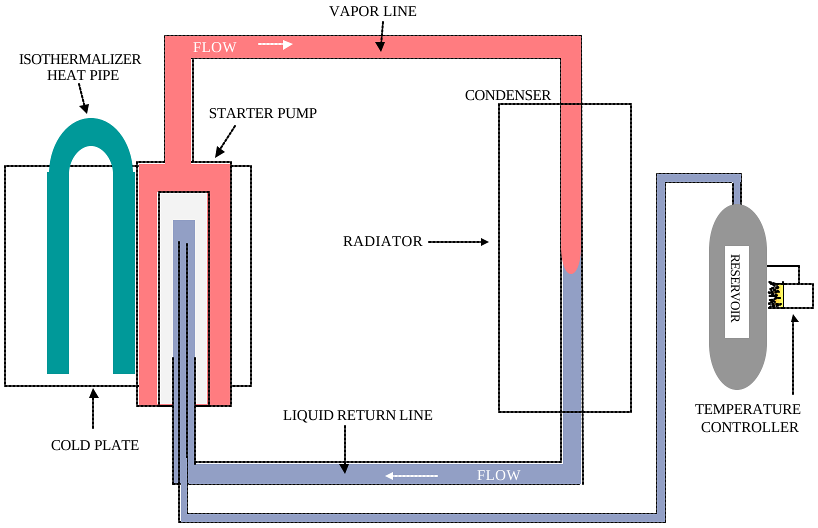
NAME	INSTITUTION
Bill Klipstein	JPL
Ann Garrison Darrin	JHU/APL
Elizabeth (Liz) Shinn	AFRL
Phil Howerton	NRO
Rudy Richter	ESTO
David Salay	Battelle
Lou Schuster	HQ-NASA
Barbara Wilson	JPL
Martin Buehler	JPL

Innovative Technologies: Technical Description

NO	TOPIC	TECHNOLOGY DESCRIPTION	PERSON	ORG	TRL
1	Advanced Two-Phase Thermal Control	• 1)Cryogenic two-phase heat transport device for thermal control of sensors and/or optical benches, or 2)Multi-zone system for isothermalizing large areas • Passive heat transfer devices that rely on the pumping power of a wick; no moving parts or EMI.	Ted Swanson	GSFC	3/4
2	Miniature-Loop Heat Pipes	• Miniaturized two-phase heat transport device for thermal control. • Passive heat transfer devices that rely on the pumping power of a wick; no moving parts or EMI.	Dan Butler	GSFC	2
3	ElectroHydroDyna-mic (EHD) Pumped Thermal Control Systems	• Thermal Control System driven by electrical forces arising from the application of an electric field to a dielectric working fluid • Temperature ranges from ambient to ~ 70K	Jeffrey Didion	GSFC	4
4	Deployable Concentrating Solar Cell Array	• NRL's thin film, specular reflectors with catenary suspension provide 43% more Watts/kg than the channel concentrator design available today. • The pointing accuracy is not as critical as with lens- type solar concentrators.	Michael Brown	NRL	4
5	Spacecraft Charging	• Measures floating potential of conducting wire or strip embedded in dielectric • Existing version has 12 samples/conductors can be at any depths in dielectric • Deep charging, internal charging, and surface charging can be measured • Technology inherently robust, charge field mechanically chopped	Richard Worsfold	CRESTe ch	~5
6	Flight Qualification Techniques	• Develop measures of effectiveness for evaluating existing and future qualification standards.	W. "JR" Dreier, Jr.	Center for Naval Analysis	5-7
7	Sensor Craft	• Spectrometer: Lightweight optical structures, carbon-carbon housing, miniature optical design • Detector: High Resolution, deep well photodiode/CCD hybrid • Single system computer, on-board signal processing	Barry Meredith, Clayton Turner	LaRC	5/6
8	Terrestrial Fluorescence	• Fabry-Perot filters, similar in nature to those on UARS/HRDI (8 years in orbit), will be used to measure surface radiance within Fraunhofer lines. • The measurement of two Fraunhofer lines per scene can be accommodated within the constraints of the orbital dynamics.	Arnold Theisen	Stennis	4/5
9	Quantum Technology	• Gravity gradiometer based on interferometric measurements using atom (de Broglie) waves.	Bill Klipstein	JPL	2/3
10	MEMS/Nano scale	• Flat Plasma Spectrometer with MEMs collimator and milli-scale HVPS are examples of a micro-technology that reduces volume, weight, mass, and power while maintaining scientific integrity of data.	Garrison Darrin	JHU/AP L	3

1. ADVANCED TWO-PHASE THERMAL CONTROL

Standard Starter Pump Capillary Pumped Loop



Flight Validation Rationale:

- This technology is very gravity sensitive.
- Justification based on zero-gravity effects on basic thermophysics of the process. In particular, the liquid phase has start-up issues.

Validation Concept:

- Could be accommodated on Hitchhiker or ISS.
- Can be either backup or primary technology.

Presenter:

- Ted Swanson: GSFC

Technology Description (two variants):

- 1)Cryogenic two-phase heat transport device for thermal control of sensors and/or optical benches, or 2)Multi-zone system for isothermalizing large areas
- Passive heat transfer devices that rely on the pumping power of a wick; no moving parts or EMI.

Performance:

- Capable of large (kW+) to small (mW) heat loads
- Transport over long distances (meters+) with very small temperature drops
- Tight temperature control (fractions of a degree)
- High reliability
- Isothermality over large areas

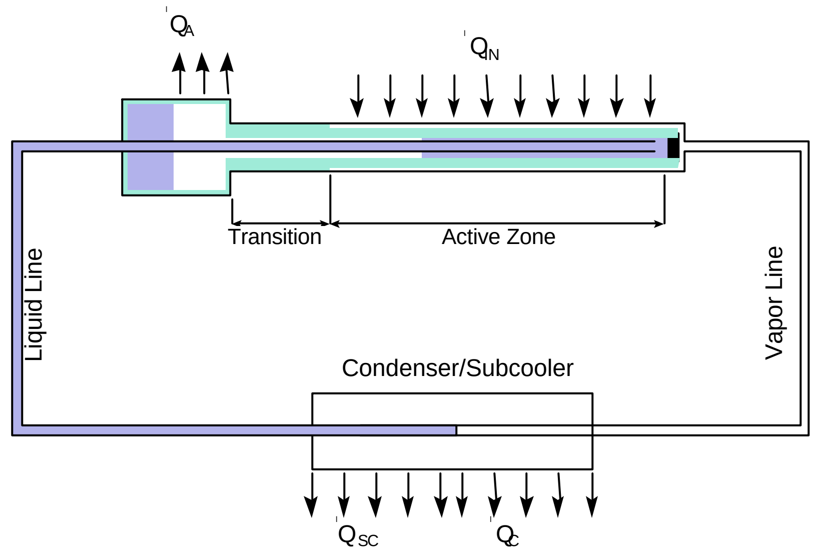
TRL:

- For T < 75 K, technology is at TRL3/4.
- Prototype ground demo, FY03; Flight demo, FY04
- For multi-zone system, TRL4.
- Prototype ground demo, FY03; Flight demo, FY04

Potential Missions:

- Missions with sensors or optical benches or electronics requiring temperature control in the ~20K to 75 K range.
- Thermally stabilize lightweight large-area deployable antennas and deployable telescopes.
- Cool high flux lasers.

2. MINIATURE LOOP HEAT PIPE



Flight Validation Rationale:

- This technology is very gravity sensitive.
- Justification based on zero-gravity effects on basic thermophysics of the process and liquid/vapor fluid management. Performance can be affected by reduced size, which does not scale linearly.

Validation Concept:

- Could be accommodated on Hitchhiker, ISS or technology demonstration spacecraft.
- Can be either backup or primary technology.

Presenter:

- Dan Butler, GSFC

Technology Description:

- Miniaturized two-phase heat transport device for thermal control.
- Passive heat transfer devices that rely on the pumping power of a wick; no moving parts or EMI.

Performance:

- Capable of heat loads ranging from 1 W to 10 W at temperatures ranging from -90 C to + 90 C
- Diode (shutdown) feature significantly reduces heater power requirements
- Tight temperature control (fractions of a degree)
- High reliability
- Evaporator size 6 mm OD, lines 1.6 mm OD
- Weight less than 150 grams

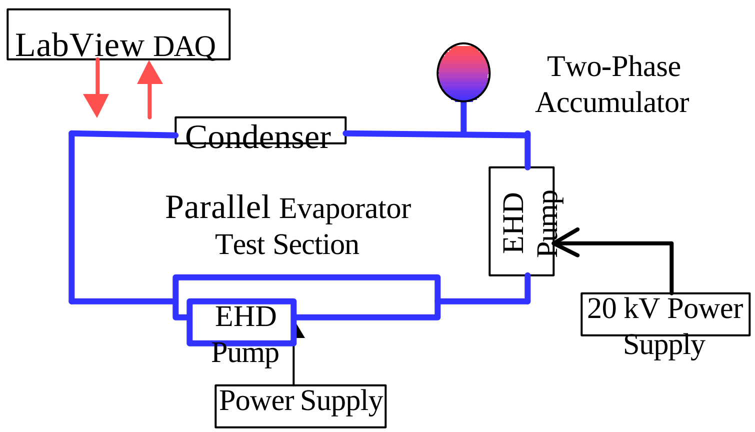
TRL:

- Current Technology is at TRL 2.
- 2 year SBIR program to TRL 4/5 by FY ‘03
- 3 year CETDP program to TRL 5/6 by FY ‘04.
- Flight demo possible in FY‘05.

Potential Missions:

- Nanosatellites with long eclipse periods
- Electronics and sensor cooling
- Mars Rovers
- Cool high flux lasers.

3. ELECTROHYDRODYNAMIC (EHD) THERMAL CONTROL LOOP



Flight Validation Rationale:

- Two-phase flow & pressure perturbations are gravity dependant
- Micro-scale heat transfer & hydrodynamics are undefined < 1g
- EHD flow requires hours to attain steady state

Validation Concept:

- Space Shuttle Flight Demonstration: Hitchhiker
- ISS
- Primary or Back-up Technology

Presenter:

- Jeffrey Didion, GSFC

Technology Description:

- Thermal Control System driven by electrical forces arising from the application of an electric field to a dielectric working fluid
- Temperature ranges from ambient to ~ 70K

Performance:

- Single Phase or Two-Phase System
- Heat Load up to hundreds of watts
- Meso-scale or micro-scale system
- Low Power consumption (~ 0.25 W)
- Lightweight
- No moving parts
- Simple Feedback Control System w/ no time inertia
- Very low acoustic noise

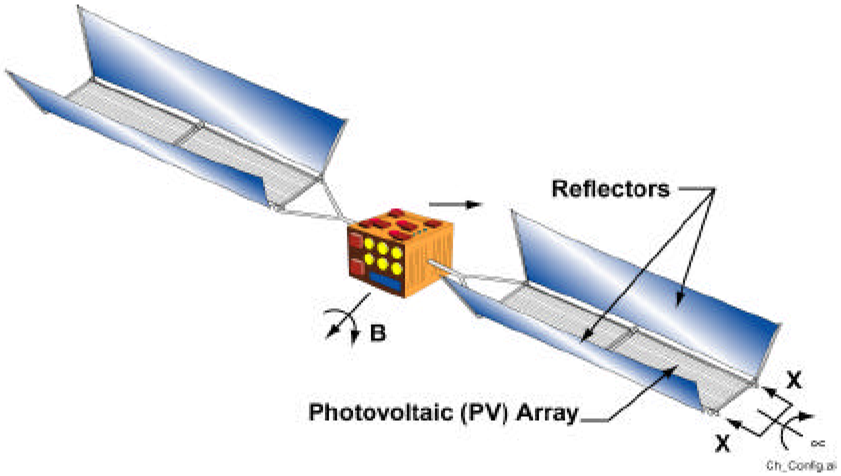
TRL:

- TRL Level 4; Laboratory Breadboard Loop
- FY02 Prototype Testing Meso&MEMS Scale
- FY03 Flight Hardware Development
- FY04 Flight Demonstration

Potential Missions:

- Instruments requiring localized cooling
- Cooling near 70 K

4. DEPLOYABLE CONCENTRATING SOLAR CELL ARRAY



Technology Description:

- NRL's thin film, specular reflectors with catenary suspension provide 43% more Watts/kg than the channel concentrator design available today.
- The pointing accuracy is not as critical as with lens-type solar concentrators.

Performance:

- Provides 175 W/kg (beginning of life) array power with state-of-art (28% efficiency) cells and also with half the stowed volume of equivalent plane array.
- Unlike Fresnel lens arrays, this concentrator generates power in the stowed position.

• TRL:

- Currently technology is at TRL4.
- Year 1: Mechanical model system development validated in thermal-vacuum environment to demonstrate TRL5.
- Year 2: Protoflight system with full flight acceptance tests to demonstrate TRL6.
- Year 2 end: Flight hardware delivered.

Potential Missions:

- Missions that can be powered by solar cells.

Flight Validation Rationale:

- Deployment of the reflectors cannot be adequately simulated on the ground.

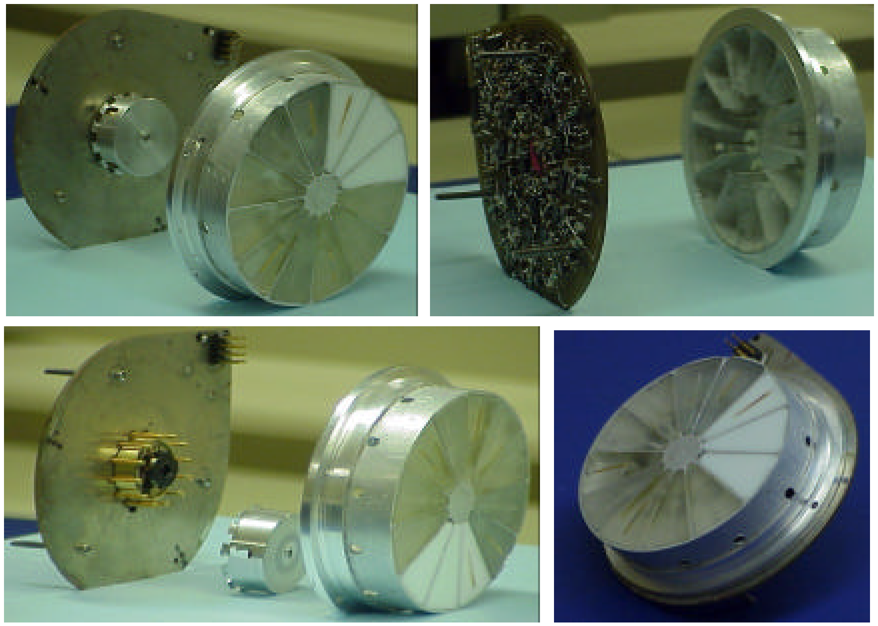
Validation Concept:

- This technology can be used as a primary payload.
- Experiment will include video to verify the deployment and characterization to capture the power, thermal, and the static and dynamic structural behavior.

Presenter:

- Mike Brown, NRL

5. SPACECRAFT CHARGING



Flight Validation Rationale:

- Enables real-time assessment of spacecraft charging threat due to energetic electrons, with lead-time for corrective action
- Tracks charge accumulation and slow charge decay as well as occurrence of impulsive discharge events
- Output is a worst-case voltage which is readily interpretable

Validation Concept:

- Measurements can be related to independent electron spectra measurements on board same or other satellites
- Correlation possible with satellite anomalies

Presenter:

Richard Worsfold, CRESTech

Technology Description:

- Measures floating potential of a conducting wire or strip embedded in a dielectric
- Existing version contains 12 samples
- Conductors can be at any depths in dielectric
- Deep charging, internal charging, and surface charging can be measured
- Technology inherently robust, charge field mechanically chopped

Performance:

- With a 100 millicurie Strontium-90 electron source simulating a magnetic storm at synchronous orbit, floating potentials to 12 kV have been measured
- Continuous long-duration lab tests lasted 3 and 4 weeks with no problems
- Flight-like construction works with OTS parts; power consumption: 2 W; weight: 200 g.

Missions:

- GEO, MEO and GEO-transfer orbits most relevant LEO also relevant through auroral oval
- Mounting can be exterior or interior, and device can be shielded with metal foil

Concept & Hardware Development:

Keith Balmain, University of Toronto, with Peter Kremer and Gerald Dubois

6. FLIGHT QUALIFICATION TECHNIQUES

Flight Validation Rationale:

- Documenting and seeking effective space qualification addresses NMP's goal of "reducing development times and life cycle mission costs."
- Flight validation is the final test for space qualification standards.

Validation Concept:

- Create database of currently required space qualifications for earth science equipment.

Presenter:

- W. Dreier, Jr., Center for Naval Analysis

Technology Description:

- . Develop measures of effectiveness for evaluating existing and future qualification standards.

Performance:

- Measure risk mitigation through reducing current qualification requirements.

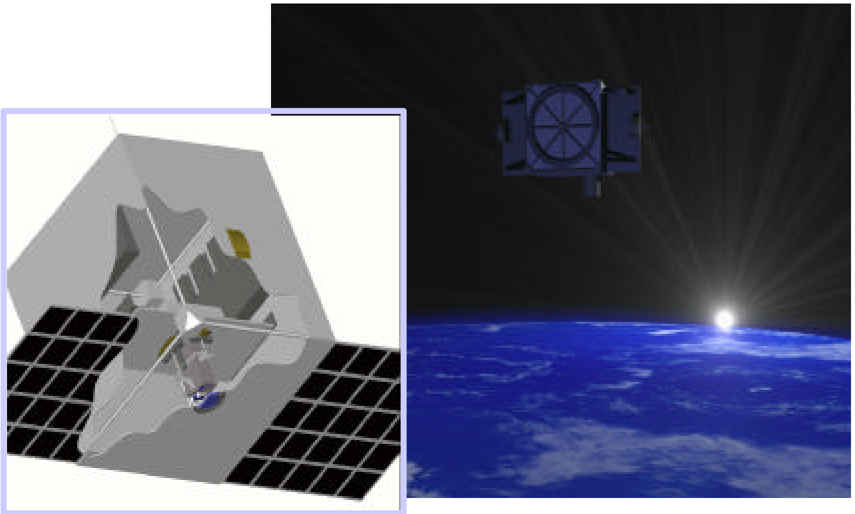
TRL:

- Qualification Procedures should be flight validated when the procedure has matured to TRLs 5-7.

Potential Missions:

- NMP's ESE Objective 3.1 includes instrument architectures.
- All ESE missions.

7. SENSORCRAFT



Flight Validation Rationale:

- Demonstrate to community via space flight, capability to build low cost, light weight, robust system with good science return
- Mature to space flight & gain acceptance for key technologies that enable above
- Demonstrate flexibility & gain acceptance of on board processing system

Validation Concept:

- Sensorcraft could be built and space flight validated under NMP or similar; could also serve as test bed for other emerging technologies

Presenter:

- Barry Meredith, NASA Langley Research Center

Technology Description:

- Spectrometer: Lightweight optical structures, carbon-carbon housing, miniature optical design
- Detector: High Resolution, deep well photodiode/CCD hybrid
- Single system computer, on-board signal processing

Performance:

- Spectral Range: 430 to 1020 nm
- Spectrometer S/N: 3000
- Vertical Resolution: less than 1.5 km
- Spectral Resolution : 0.58 nm
- Detector Full Well: 6M (photodiode), 17M (readout CCD)
- On board processing delivers answers, a four order of magnitude reduction in down linked data

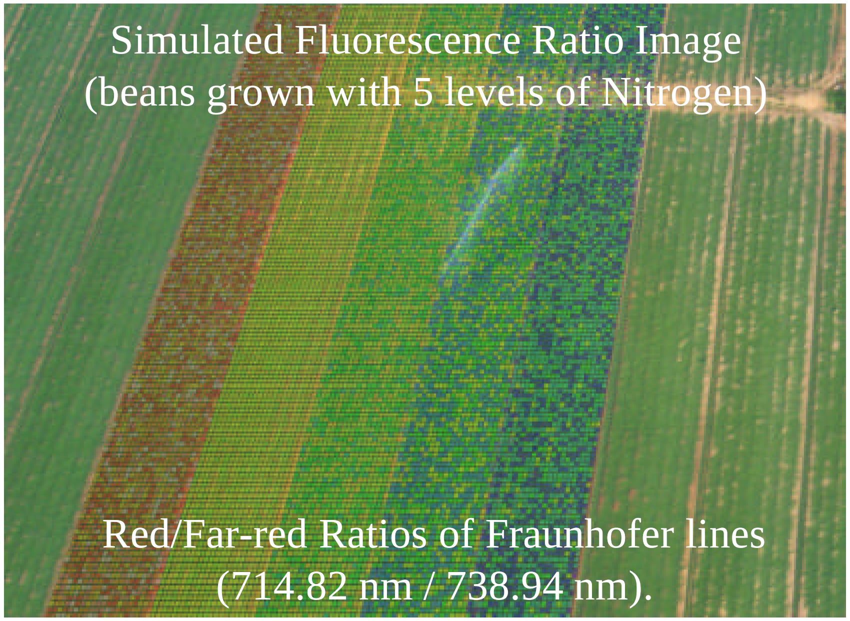
TRL:

- Key Subsystems currently at TRL 5/6
- Full Sensorcraft space flight validation/demo possible with possible in 24-36 months after ATP

Potential Missions:

- NMP (Sensorcraft), Technology Development / Validation (Sensorcraft / subsystems), Flights of Opportunity (subsystems)

8. TERRESTRIAL FLUORESCENCE



Flight Validation Rationale:

- Extreme narrow band Fraunhofer lines will be used to measure fluorescence.
- Confirmation of atmospheric effects models from orbit are required.

Validation Concept:

- Either Hitchhiker or ISS would meet orbital needs.

Presenter:

- Arnold Theisen, NASA/SSC/GADD (NRC)

Technology Description:

- Fabry-Perot filters, similar in nature to those on UARS/HRDI (8 years in orbit), will be used to measure surface radiance within Fraunhofer lines.
- The measurement of two Fraunhofer lines per scene can be accommodated within the constraints of the orbital dynamics.

Performance:

- Statistical analysis and modeling indicate that the ratio of two Fraunhofer lines would be highly successful in monitoring vegetation fluorescence.
- Radiometer and imaging measurements have been made at aircraft altitudes for one of the several wavelengths proposed for the new system.

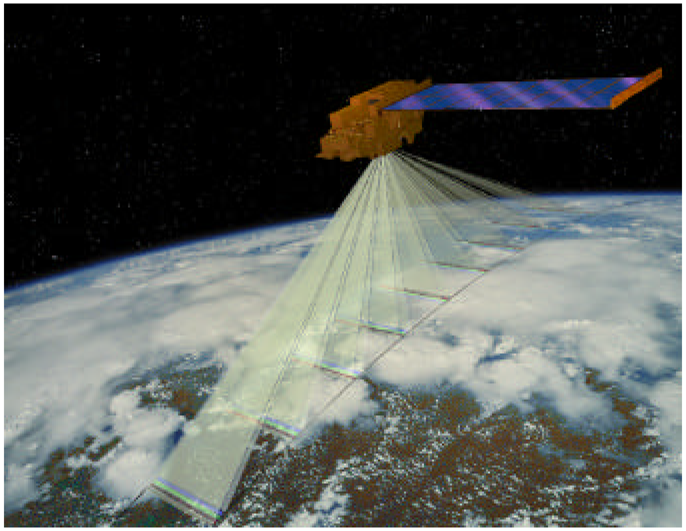
TRL:

- A new system is estimated to be at TRL 4 or 5.

Potential Missions:

- Vegetation science of pre-selected sites undergoing stress from air pollution, insect infestation, nutrient shortage, drought, etc.
- Specific applications exist for precision agriculture, forestry, remediation and recovery monitoring, and wetlands and coastal biosphere management.

9. QUANTUM TECHNOLOGY



Flight Validation Rationale:

- The high sensitivity of Quantum Atom Gravity Gradiometer is realizable only in the space environment

Validation Concept:

- Could be accommodated on a Shuttle or ISS mission
- Can be used as a primary payload

Presenter:

- Bill Klipstein, JPL

Technology Description:

- Gravity gradiometer based on interferometric measurements using atom (de Broglie) waves.

Performance:

- Potential for extending the current sensitivity limit of mechanical, earth based instruments at1 Eotvos by up to six orders of magnitude in space.

TRL:

- Technology is currently at TRL 2/3 level. Current plans are for a flight demo prototype by 2005.

Potential Missions:

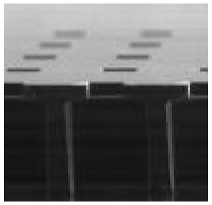
•Earth and Planetary Interiors:

Lithospheric thickness, composition
Lateral mantle density heterogeneity
Deep interior studies
Translational oscillation between core/mantle

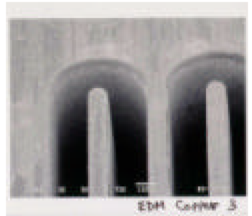
•Earth and Planetary Climate Effects:

Surface and ground water storage
Oceanic circulation
Tectonic and glacial movements
Tidal variations

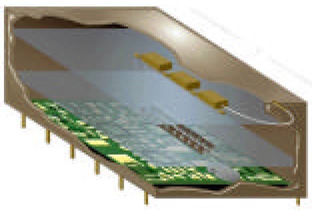
10. MEMS/NANO TECHNOLOGY (Flat Plasma Spectrometer)

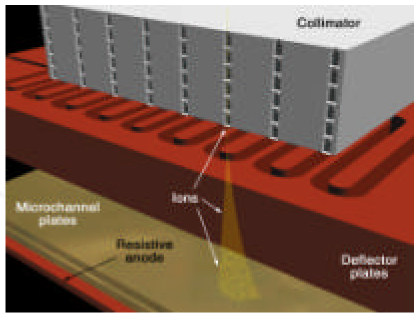


MEMs Collimator



Milli scale HVPS





Prototype Flat Plasma Spectrometer- MEMs Collimator, Meso Scale Deflector and Milli Scale High Voltage Power Supply (HVPS)

Flight Validation Rationale:

- Science Enabling Technology , flight validations to assure environmental application full functionality

Validation Concept:

- Due to the miniaturized scale, this demonstration could be easily inserted as an add-on in traditional instrument space.

Presenter:

- Ann Garrison Darrin, JHU/APL

Collaborator:

- Carlos Urdiales, SwRI

Technology Description:

- Flat Plasma Spectrometer with MEMs collimator and milli-scale HVPS are examples of a micro-technology that reduces volume, weight, mass, and power while maintaining scientific integrity of data.

Performance:

- 1-2 Orders of magnitude reduction in size for insertion in micro and nano satellites (ex. 10 to 20 kg conventional spectrometer reduced to 100 gram instrument)
- On orbit programmable HVPS ultra lightweight power supply is polarity configurable.

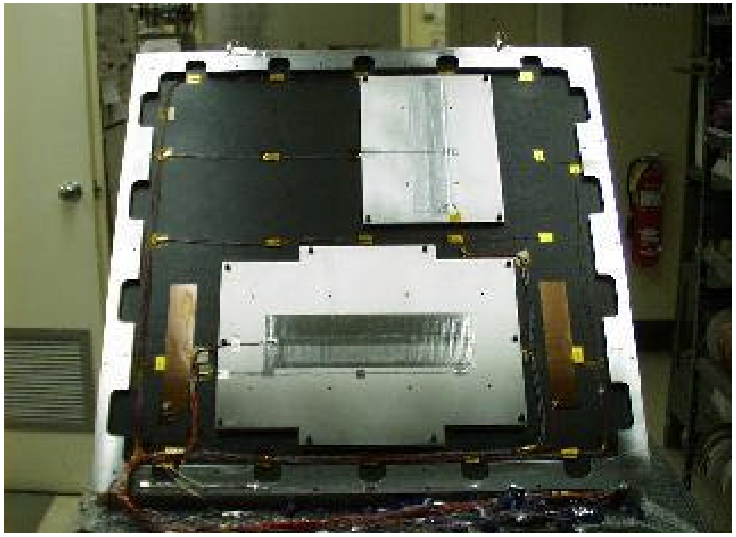
TRL:

- Current TRL of 3
- Year 1 - complete engineering model and demonstrate concept feasibility
- Year 2 - Protoflight system and ground based qualification test
- Year 3 - On orbit test validation

Potential Missions:

•Thermosphere: MTM and MDM-Wind, temperature, density
•Ionospheric features Ion-drift, composition, E and B
•Low-latitude Plasma Science-Electron velocity distributions
•Fluorescence spectroscopy (X-ray UV visible)
•Nuclear recoil detector lasers

11. ADVANCED CARBON/CARBON STRUCTURAL RADIATOR



EO 1 C/C structural radiator in test mounting

Technology Description:

- Advanced lightweight composite structural material with graphite foam honeycomb

Performance:

- Increased isotropic thermal conductivity, thinner and lighter weight structures

TRL:

- Advanced composites are at TRL5, but new sandwich construction with advanced materials are at TRL4

Potential Missions:

- The structural radiator concept works for any mission and is especially effective for payloads with large waste heat

Flight Validation Rationale:

- Advanced structural and radiator concepts need flight validation for new materials because they are a new approach.

Validation Concept:

- Carbon/carbon facesheets on graphitic foam with embedded thermistors for on orbit data.

Presenter:

- Elizabeth (Liz) Shinn, AFRL, 937-255-9162

CONCEPTUAL DESIGN

C/C FACESHEETS ON GRAPHITIC FOAM WITH ONE BEING OPTIONAL

Relation Between Innovative Technologies and Other Breakout Sessions

BREAKOUT SESSION TOPIC	*THERMAL CONTROL*	*SOLAR CONCEN-TRATORS*	*SPACE ENVIRON. 2*	*FLIGHT QUAL.*	*SENSOR CRAFT*	*TERRESTRIAL FLUORESCENCE*	*QUANTUM MEMS NANO TECH.*	*CARBON/ CARBON STRUCTURE*
ANTENNAS	**Geometric stability**	**1**	**Passive antenna charging**	**4**	**na**	**na**	**5**	**LTWT thermally stability**
HIGH RATE COMM.	**Stability of optical antenna**	**1**	**3**	**4**	**na**	**na**	**5**	**6**
TELESCOPES	**Thermal stability**	**1**	**3**	**4**	**na**	**na**	**5**	**LTWT thermally stability**
DISTRIBUTED S/C	**General purpose robust design**	**1**	**3**	**4**	**Precursor experiment to sensor web**	**na**	**5**	**6**
NAVIGATION	**na**	**1**	**3**	**4**	**na**	**na**	**5**	**6**
ON-BOARD DATA PROCESSING	**Chip cooling**	**1**	**3**	**4**	**In-board DSP for science data processing**	**na**	**5**	**6**
INTEGRATED OPTICS	**Detector thermal stability**	**1**	**3**	**4**	**High S/N grating specification**	**Enhances optical data acquisition**	**5**	**6**
LASER TECHNOLOGY	**High heat flux**	**1**	**3**	**4**	**na**	**na**	**5**	**LTWT thermally conductive**

1. Increases s/c specific power ratio
2. ESD monitors and mitigation technology
3. Needed for unshielded very small S/C.
4. Requirement levied on provider to reduce flight qualification
5. Low TRL technology which needs to be monitored for future use
6. Potential mass/thermal benefit